3068-4-2-7

WORKING PAPER ONLY - DO NOT QUOTE
DOCUMENT DE TRAVAIL SEULEMENT - NE PAS CITER

The Propensity to Patent and the Major Beneficiaries of the US Patent System

Alexander W. Jenkins
Department of Economics
University of Alberta

January 1982

Summary Report

The views presented in this paper are those of the authors and do not necessarily reflect the views or positions of the Department of C.C.A.

1. INTRODUCTION

In an earlier study dealing with the Canadian patent system (Gillen, Jenkins and Riddell [1980]), models of research and development (R and D) activity, patenting and profitability are developed and estimated using data for Canadian firms. It is the purpose of this study to further refine these models and to estimate them for samples of U.S. firms (for which a more complete time series of R and D, patent and financial data are available).

As is to be expected, the estimated results prove to be much more satisfactory in terms of the degree of explanation achieved and the cross-sample consistency of the causal relationships. For the separate samples of chemical, electrical, machinery and transportation equipment firms, innovative activity appears to be encouraged by some barriers to entry (eg. an absolute capital or vertical integration barrier increases appropriability) and discouraged by others (eg. product differentiation barriers to entry due to advertising seem to act as a good substitute for technological innovation as both an entry barrier and a form of non-price competition). No consistent relationship emerged between market concentration and innovative activity, suggesting that a vigorous competition policy (accompanied by an effective patent system) would enhance static efficiency without harming dynamic efficiency.

There is no indication of excess profitability resulting from patenting activity. It would seem, therefore, that the

patent system is providing desired protection to competitive innovators without unduly enhancing profits for innovators in highly concentrated, entry-protected industries. If patent reform is needed, patent breadth and duration might be increased for innovators in competitive industries.

The next section provides an update of the literature reviewed in the earlier Canadian study. A third section develops estimable models of R and D, patenting and profitability. The fourth section outlines the data, samples, variables and estimation techniques used in the empirical examination of these models. A fifth section presents and briefly analyzes the regression results while the last section outlines the major policy implications and conclusions of the study.

2. LITERATURE UPDATE

In implementing the empirical portion of the previous (Canadian) study, a serious weakness in one important study of R and D activity was revealed. It was found that the correction for market concentration - a linear term in the Herfindahl index - employed by Howe and McFetridge [1976] in specifying their R and D equation appeared to be inappropriate. In particular it was ascertained that market concentration should be weighted by a measure of firm size (sales) so that the effect of concentration on R and D would be proportionally larger for large than for small firms within the same industry. By so doing, statistical results for the coefficient of concen-

tration were obtained which were both more robust and of greater statistical significance in general than those of Howe and McFetridge.

One study of considerable importance to an examination of R and D, patenting and profitability is not reviewed in the Canadian study. This is the study by Grabowski and Mueller [1978] in which industrial research and development expenditures are viewed as net and replacement investments for an "intangible capital stock". This intangible capital stock gives rise to barriers to entry which in turn facilitate higher profits in future periods. However, this intangible capital stock depreciates over time due to market satiation and the development of superior substitute technology.

Grabowski and Mueller suggest that the typical measurement of profitability in previous studies has been computed as follows:

$$(1) \qquad PR_t = (Sales_t - Variable\ Costs_t - \lambda_t K_t - R_t - A_t)/K_t$$

where

K_t = total tangible assets in period t

λ_K = depreciation rate for tangible assets

R_t = R and D expenditures in period t, and

A_t = advertising expenditures in period t.

Recognizing that the effects of R and D and advertising persist over several periods, they then argue that the correct profit rate should be written:

$$(2)\quad PR^*_t = (\text{Sales}_t - \text{Variable Costs}_t - \lambda_K K_t - \lambda_R K^R_t - \lambda_A K^A_t)/(K_t + K^R_t + K^A_t)$$

where K^R_t and K^A_t are the capital stocks from past R and D and advertising expenditures and λ_R and λ_A are their respective rates of depreciation.

They next assume a Koyck distributed lag structure along with a constant proportional depreciation rate over time so as to be able to write the R and D and advertising capital stocks as follows:

$$(3)\quad K^R_t = \sum_{k=0}^{\infty}(1-\lambda_R)^k R_{t-k} \qquad \text{and}$$

$$(4)\quad K^A_t = \sum_{k=0}^{\infty}(1-\lambda_A)^k A_{t-k}$$

They then incorporate equation (2) into a traditional profitability equation to generate the corrected profitability equation:

$$(5)\quad PR^* = f(K^R/(K + K^R + K^A),\ K^A/(K + K^R + K^A),\ CR,\ GR,\ S)$$

where CR is the industry four-firm concentration ratio, GR is the industry growth rate and S is a measure of firm size (eg. sales).

Estimation would be necessarily non-linear since after substituting equations (2), (3) and (4) into equation (5) the values of λ_R and λ_A would be adjusted along with the other parameters of the explanatory variables so as to maximize the goodness of fit of the equation.

Alternatively we could rewrite equation (5) as follows (ignoring time subscripts):

(6) Sales - Variable Costs - $\lambda_K K$

$$= (K + K^R + K^A) f(K^R/(K + K^R + K^A),\ K^A/(K + K^R + K^A),\ CR,\ GR,\ S) + \lambda_R K^R + \lambda_A K^A$$

Simplifying further by assuming linearity gives the result:

(7) Sales - Variable Costs - $\lambda_K K$

$$= (a_R + \lambda_R)K^R + (a_A + \lambda_A)K^A + a_C(K + K^R + K^A)\ CR + a_G (K + K^R + K^A)GR + a_S(K + K^R + K^A)S + a_T(K + K_R + K_A)$$

Again estimation would be non-linear (with respect to right hand variables only) after substituting equations (3) and (4) into the right hand side of equation (7). We would choose the values of λ_R, λ_A and the a's so as to maximize the goodness of fit. Needless to say, the presence of heteroscedasticity would be highly probable so both sides of equation (7) might be weighted by the reciprocal of sales (or some other measure of firm size) in order to achieve efficient estimation.

A more general approach to estimating equations (5) and (7) would involve assuming an irregularly time-variant rate of depreciation for R and D and advertising. We would proceed by substituting a distributed lag function of R and D and advertising expenditures for K^R and K^A respectively. We would then determine the weights of this function by a non-linear estimation of equation (5) or (7). We would, however, face the

disadvantage of dramatically reduced degrees of freedom and multicollinearity in the event of a long distributed lag function.

The findings of Grabowski and Mueller also have implications for studies of R and D and patenting activity. In order to maintain a sufficiently (profit-maximizing) high level of entry barriers, the amount of R and D spending in a given year would have to include a portion adequate to replace the depreciated portion of the previous year's stock of R and D and also possibly to increase entry barriers which are exhibiting secular weakness. Moreover, the marginal cost of funds and the flexible accelerator models discussed in the next section explain current R and D expenditures in terms of current sales and other variables along with lagged R and D stock. In any case, a measure of R and D stock similar to that given in equation (3) should be included as an explanatory variable in the R and D equation.

3. R AND D, PATENT AND PROFITABILITY MODELS

A. Specifying the R and D Model

In light of Grabowski and Mueller's treatment of R and D as an investment activity, we will seek to adapt two of the widely used models of fixed business investment (see Evans [1969, Chapter 4]) to our explanation of innovative activity. We have already discussed the first model in our previous report - the marginal cost of funds theory. We will briefly summarize this model below. We will then undertake a more

extensive discussion of the second model - the flexible accelerator theory.

a. The Marginal Cost of Funds Model

The maximization of the present discounted value of the firm requires that the firm's level of spending on R and D be such that, for the last project undertaken/dollar spent, the marginal internal rate of return (MRR) be equal to the marginal cost of funds (MCF). Both MRR and MCF depend upon the level of net R and D spending (R_n), inversely and directly respectively, along with vectors of other (exogenous) variables, W and Z respectively. In symbols

(8) $MRR = f(R_n, W)$

(9) $MCF = g(R_n, Z)$

and for a present value maximum,

(10) $f(R_n, W) = g(R_n, Z)$

Solving equations (8)-(10) yields the reduced form R and D equation:

(11) $R_n = h(W, Z)$

and for gross R and D expenditures:

(11)' $R = h(W, Z) + \lambda_R KR_{-1}$

Variables included in vector W, with probable impact on MRR specified in brackets to be positive (+), negative (-), or unknown (?), include capital intensity (-), rate of

growth of industry demand (+), firm size (+ for the first order term), industry concentration (?), entry barriers (?), and specialization (?). Variables included in vector Z which affect MCF include the rate of growth of industry demand (-), conglomerateness (-), and government grants (-). Variables increasing (decreasing) MRR will tend to increase (decrease) the level of R and D spending, while variables increasing (decreasing) MCF will tend to decrease (increase) the level of R and D spending.

b. The Flexible Accelerator Model

We begin by postulating that the level of R and D stock (KR) depends upon sales (S) along with other variables (V) such as barriers to entry, concentration, conglomerateness et cetera. Next we define a vector O as a linear combination of S and V. We now write the R and D stock at time t as a Koyck distributed lag function of O, ($0 < \lambda < 1$):

$$(12)\quad KR_t = \alpha(1-\lambda)[O_t + \lambda O_{t-1} + \lambda^2 O_{t-2} + \ldots + \lambda^k O_{t-k} + \ldots]$$

$$(13)\quad \lambda KR_{t-1} = \alpha(1-\lambda)[\lambda O_{t-1} + \lambda^2 O_{t-2} + \ldots + \lambda^k O_{t-k} + \ldots]$$

Subtracting equation (13) from (12) and rearranging yields the result (assuming $\lambda^T = 0$ for large T):

$$(14)\quad KR_t = \alpha(1-\lambda)O_t + \lambda KR_{t-1}$$

Now current gross R and D expenditures (R_t) are the sum of net R and D expenditures, $R_{nt} = KR_t - KR_{t-1}$, and replacement investment, $\lambda_R KR_{t-1}$. We write this as follows:

(14)' $R_t = KR_t - KR_{t-1} + \lambda_R KR_{t-1}$

We use this result to rewrite equation (14):

(15) $R_t = \alpha(1-\lambda)O_t + (\lambda + \lambda_R - 1)KR_{t-1}$

We can interpret equation (15) as stating that current R and D expenditures depend upon a linear function of current sales, concentration and other variables and the lagged value of the R and D stock. The latter is computed as per equation (3), specifically

(16) $KR_{t-1} = \sum_{k=1}^{\infty}(1-\lambda_R)^k R_{t-k}$

If we were to insert equation (16) into equation (15) we could then use a non-linear estimation technique to estimate all parameters of equation (15), including λ_R. Alternatively, we could assume KR_{t-1} to be a general linear distributed lag function of previous R and D expenditure and estimate equation (15) using ordinary least squares (albeit with fewer degrees of freedom).

B. Specifying the Patent Model

Patents are viewed as a potential result of previous R and D expenditures. Whether or not relevant R and D spending is transformed into a patent depends upon the propensity to patent. This propensity is a function of the

nature of the innovation (product or process), industry concentration, barriers to entry and other variables discussed in our previous study. Specifically the level of patenting activity during period t, measured as patents applied for or patents granted during period t, is explained as follows:

$$(17)\quad P_t = \emptyset\,(R_t, R_{t-1}, \ldots R_{t-T}, X_t, X_{t-1}, \ldots X_{t-T})$$

where X is a vector of the other variables discussed above and T is the maximum R and D - patent application/issue lag.

If we assume a Koyck distributed lag function between patent applications (rather than grants, which are subject to an additional lag) and both R and X (with coefficients α and vector β respectively), we can rewrite the patent equation in linear form as follows:

$$(18)\quad P_t = \alpha(1-\lambda)[R_t + \lambda R_{t-1} + \ldots + \lambda^T R_{t-T}] + \beta(1-\lambda)[X_t + \lambda X_{t-1} + \ldots + \lambda^T X_{t-T}]$$

or

$$(18)'\quad P_t = \alpha(1-\lambda)R_t + \alpha(1-\lambda)RK_{t-1} + B(1-\lambda)[X_t + \lambda X_{t-1} + \ldots + \lambda^T X_{t-T}$$

for $RK_{t-1} = [\lambda R_{t-1} + \ldots + \lambda^T R_{t-T}]$

Equation (17), (18) or (18)' can be estimated directly. If, however, data on previous R and D are not available, we can proceed as follows.

From equation (18) (again assuming $\lambda^T = 0$ for large T) it follows that:

$$(19)\quad \lambda P_{t-1} = \alpha(1-\lambda)\,[\lambda R_{t-1} + \lambda^2 R_{t-2} + \ldots + \lambda^T R_{t-T}] + \beta(1-\lambda)[\lambda X_{t-1} + \lambda^2 X_{t-2} + \ldots + \lambda^T X_{t-T}]$$

Subtracting equation (19) from equation (18) and rearranging yields the result:

$$(20)\quad P_t = \alpha(1-\lambda)R_t + \beta(1-\lambda)X_t + \lambda P_{t-1}$$

We can estimate equation (20) (for current data on P, R and X and once-lagged P) using a linear estimation technique to obtain parameter values for α, β, and λ. By so doing we would need fewer degrees of freedom than in estimating either (17) or (18).

An alternative approach to examining the determinants of the propensity to patent would involve the use of patents as a direct measure of innovative activity. We would estimate an equation equivalent to equation (11)' but specifying patent applications as the dependent variable and using vectors of current values of the exogenous variables W and Z as the explanatory variables (and also lagged values in order to capture the R and D-applications). A simplifying Koyck or other distributed lag function could be assumed. In symbols,

$$(21)\quad P_t = \Psi(W_t, W_{t-1}, \ldots W_{t-T}, Z_t, Z_{t-1}, \ldots Z_{t-T})$$

If we were to employ the accelerator rather than the marginal cost of funds model, we would estimate the analogue to equation (15). In symbols, we would estimate:

$$(22) \quad P_t = \alpha(1-\lambda)O_t + (\lambda + \lambda_p - 1)KP_{t-1}$$

where KP_{t-1} is the stock of patents existing during the previous period computed as follows:

$$(23) \quad KP_{t-1} = \sum_{k=1}^{\infty}(1-\lambda_p)^k P_{t-k}$$

Since error terms might be log-normally distributed for patents, equations (21) and (22) might be specified in logarithmic form. Equation (22) would in any event be estimated using non-linear estimation techniques.

Elasticity comparisons for variables W and Z between equations (11)' and (21) and for O between equations (15) and (22) could also provide indications of the effect of variables on the propensity to patent. For example, a higher elasticity with respect to concentration in the R and D than in the patent equation would indicate that concentrated industries have a lower propensity to patent than competitive industries.

c. Specifying the Profitability Model

Profitability can be measured as the profit-equity ratio, the profit plus interest-total asset ratio, or the profit-sales ratio, although the last measure requires a correction for capital intensity on the right hand side of

the profitability equation. In all cases profit should be computed as sales minus variable costs minus depreciation of the tangible, R and D and advertising stock. Explanatory variables typically included in the profitabilty equation, along with expected sign, (+, -, or ?) include the rate of growth of industry demand (+), capital intensity (+), concentration (+), and entry barriers (+) such as tariffs, intangible, patent and advertising stocks, economies of scale and so on.

The patent stock includes the undepreciated portion of all patents previously applied for. Prior estimation of equation (22) (after substitution of (23)) yields an estimate of the depreciation rate, λ_p. The current patent stock is then computed as follows:

$$(24) \quad KP_t = \sum_{k=0}^{\infty}(1-\lambda_p)^k P_{t-k}$$

We could now estimate equation (7) using values of KP along with or in lieu of KR in order to capture the excess profitability resulting from patenting the results of previous R and D.

D. Using the Models in a Benefit-Cost Analysis of Patents

In contrast to our previous study, we are able to use the time series observations on patents and related profits and R and D expenditures to compute the respective present discounted value of any excess profits associated with

patenting the results of previous R and D expenditures. If the coefficient of the patent stock variable in the profitability equation (7) implies an excess profitability (for a unit increase in KP_t) equal to π_p for a firm of specified characteristics, we could compute the present discounted value of the benefit of patenting the relevant R and D over the effective patent life as follows:

$$(25) \quad PDVB = \pi_p \sum_{k=0}^{T} (1-\lambda_p)^k/(1+r)^k$$

where r is the discount rate and λ_p is the depreciation rate of the patent stock.

We also compute the present discounted value of developing the patentable invention for a firm of the same specified industry and characteristics as follows:

$$(26) \quad PDVC = \sum_{t=0}^{T} (1+r)^t/\alpha(1-\lambda)^T \sum_{k=0}^{T} \lambda^k$$

where we have totally differentiated equation (18) with respect to P and R (setting the R's equal in all years), set dP = 1 and solved for $dR = 1/\alpha(1-\lambda)^T \sum_{k=0}^{T} \lambda^k$.

Comparing the ratio of PDVB to PDVC for firms of particular characteristics (eg. firms from concentrated and unconcentrated industries) provides us with an indication of those firms/industries (with higher positive ratios) where a reduction in patent life would least damage the incentive to innovate and at the same time provide for earlier consumer benefits upon patent expiry.

4. DATA, SAMPLE, VARIABLES AND ESTIMATION TECHNIQUE

Data are drawn from many sources. Patent data (an aggregate of product and process patents) for individual U.S. firms and/or their subsidiaries are reported annually 1966-77 in the OTAF tape provided by the U.S. government. Financial data (in millions of current dollars) for the years 1961-77 are taken from Standard and Poor's Compustat. Since the OTAF data are typically unconsolidated whereas the Compustat data are consolidated by parent firm, a concordance matching subsidiaries with parents (obtained from the Department of Consumer and Corporate Affairs of Canada) is employed in aggregating the patent data up to the consolidated firm level. Industry concentration data (3 or 4 digit S.I.C. classification) are reported in the U.S. 1972 Census of Manufacturers.

Four separate samples, each consisting of consolidated firm level data, are employed. Each is drawn from a large, research-intensive 2 digit S.I.C. industry. Samples, with the number of firms presented in brackets, are constructed for chemical products, 28(80); electrical products, 36(101); machinery, 35(114); and transportation equipment, 37 (41). Sample patent and financial data are averaged for the "current" period, 1976-77, while the past patent, R and D and advertising series are defined annually 1961-75 (1966-75 for patent applications).

The three variables to be explained are R and D expenditures (R_t), patent applications (P_t), and profits, π_t.

Each is averaged for the period 1976-77 (rather than 1978-79, since patents appeared to be unreported in many cases for those years). Needless to say, 1976 values for R and D and profits are first inflated (by the GNP inflator) so as to be expressed in 1977 constant dollars. "Patent applications" is employed as the measure of patenting activity, rather than "patents granted", for two reasons. First, they are reported for a longer period (beginning in 1966 rather than 1970). Second, they are more responsive to current conditions than are "patents granted", since the latter is subject to the well known application-issue lag of about three years. Profits are computed as before tax profits plus reported interest, R and D and advertising expenditures (since R and D and advertising costs are viewed as capital outlays and estimated depreciation of the R and D and advertising stocks are implicit right hand variables, i.e. proportions of KR and KA). All three variables, R, P and π are divided by sales (S) prior to actual estimation of the respective equations (in order to reduce heteroscedasticity).

Explanatory variables frequently appeared in all three estimated equations. CR4 is the 4-firm concentration ratio (%) for the individual firm's 3 or 4 digit S.I.C. industry. IGF is the industry growth factor, computed as one plus the simple annual growth rate, 1972-77, of sales for the individual firm's 3 or 4 digit S.I.C. industry. VI is a measure of the firm's degree of vertical integration, computed as

the ratio of value added to sales ($0 < VI < 1$). RNS is a measure of firm specialization (an inverse measure of conglomerateness), computed as the reciprocal of the number of subsidiaries constituting the consolidated firm ($0 < RNS \leq 1$). S is firm sales (in millions of current dollars). KI is capital intensity, measured as the ratio of net plant to sales. FS is a measure of absolute firm size, the logarithm of assets. KAT/S is advertising stock intensity, where KAT is the undepreciated balance of advertising expenditures, 1961-77 (see equation (4)), assuming the depreciation rate, $\lambda_A = .30$, reported by Grabowski and Mueller [1978]. KAT/S performed equally well in the regressions for higher and lower assumed values of λ_A (.25, .35). R/S is current R and D intensity, while RL/S is the average R and D intensity over the previous two-year period (1974-75). KR/S is R and D stock intensity, where KR is the undepreciated balance of R and D expenditures over the period 1961-75 (see equation (16)), while KRT/S is analogously defined over 1961-77. The depreciation rate for R and D, λ_R, is computed in the nonlinear regression of equation system (15) and (16). PL/S is the patent application intensity over the previous (1974-75) period. RK/S is a weighted sum of R and D intensities, 1961-75, where weights are powers of λ. It is formulated for purposes of estimating the patent intensity equation, and is defined in equation (18)'. KP/S is the patent stock intensity, where KP is the undepreciated balance of patent

applications over the period 1966-75 (see equation (23)), while KPT/S is defined analogously over 1966-77. The depreciation rate for patent applications, λ_p, is computed in the non-linear estimation of equation system (22) and (23). KT/S the total capital stock intensity, where KT = K + KRT + KAT and K is tangible assets.

The R and D and patent intensity equations [equation system (15) and (16) and equation (18)' and system (22) and (23) respectively] are estimated in both linear and logarithmic form using non-linear least squares in order to determine λ_R, λ and λ_p respectively. These "depreciation rates" are in turn used to compute KR and KRT, RK and KP and KPT respectively. KT is computed as K + KAT + KRT. Other versions of the R and D and patent intensity equations (eg. equation (20)) as well as the profitability equation are then estimated in linear and logarithmic form using ordinary least squares, since that technique is considerably more efficient (and economical) than non-linear least squares. Variations in the values of λ_R, λ and λ_p were examined ($\pm$.20) but the explanatory power of the equations and parameter values were satisfactorily robust.

5. REGRESSION RESULTS AND ANALYSIS

The results of estimating the R and D intensity equation in both linear and logarithmic forms are presented in Tables 1 and 2 respectively. Since goodness of fit statistics are generally higher than in earlier studies, the relevance of

TABLE 1: ESTIMATED COEFFICIENTS FOR THE LINEAR R AND D EQUATIONS*

EQN, SAMPLE	UNITY	CR4	$CR4^2$	IGP	VI	RMS	1/S	S	KI	PS	$\frac{KAT}{S}$	$\frac{KR}{S}$	λ_R	$\frac{RL}{S}$	R^2
1C	-.123M1	.396M3[c]	-.493M3	-.157M1	.103M1	-.273M2	.533PO[a]	-.723M6	-.186M1[a]	.230M2[b]	-.396M1[b]	.657PO[a]	.375[a]		.97
1E	-.173M1[b]	.542M4	.463M6	.115M3	.219M1[a]	.304M2[b]	-.118M2	-.639M6	-.889M2	.207M2[b]	-.293M1	.738PO[a]	.458[a]		.91
1M	-.397M2	.271M3	-.298M5	-.410M2	.151M1[b]	.618M3	-.979M2	-.114M5[b]	-.100M1[c]	.363M3	-.743M1	1.16PO[a]	.346[a]		.92
1T	.646M2	-.122M3	.178M5	-.131M1	.157M1[b]	.366M2[b]	.187PO	-.233M6[b]	-.522M2	.847M3	-.111PO[a]	.644PO[a]	.403[a]		.93
2C	-.141M1	-.688M4	.799M6	.378M5	.127M1[b]	-.193M2	.458PO[a]	-.591M6	-.555M2	.213M2[a]	-.776M2	.321M1	.375[a]	.103P1[a]	.99
2E	-.868M2	-.462M4	.114M5	.789M3	.123M1[c]	.149M2	-.294M1	-.204M6	-.125M3	.863M3	-.163M1	.357PO[a]	.458[a]	.627PO[a]	.92
2M	-.467M2	.199M3	-.208M5	.139M2	.513M2	-.625M3	-.965M1	-.549M6	-.114M2	-.481M3	-.144M1	.358PO[b]	.346[a]	.932PO[a]	.94
2T	.843M2	-.918M5	.534M6	-.147M1	.731M2	.717M2[c]	.161PO	-.138M6[b]	-.497M2[c]	.778M3	-.569M1[c]	.144PO	.403[a]	.927PO[a]	.96
3C	-.139M1	-.955M4	.105M5	.793M3	.132M1[b]	-.193M2	.456PO[a]	-.584M6	-.505M2	.214M2[a]	-.532M2			.109P1[a]	.99
3E	-.165M2	-.182M3	.226M5	.134M2	.850M2	.118M2	-.448M1	.140M6	.441M2	-.201M4	-.585M2			.114P1[a]	.91
3M	-.510M2	.203M3	-.202M5	.351M2	.234M2	-.119M2	-.122PO[c]	-.329M6	.226M2	-.763M3	.112M1			.132P1[a]	.94
3T	.923M2	.277M4	.166M6	-.159M1[c]	.595M2	.182M2	.156PO	-.116M6[c]	-.538M2[c]	.826M3	-.444M1[c]			.117P1[a]	.96

* The dependent variable is R and D intensity, R/S. Samples: C = 80 chemical firms; E = 101 electrical firms; M = 114 machinery firms; T = 41 transportation equipment firms. Notation: .123M3 = .123 x 10^{-3} = .000123; .456P1 = .456 x 10^{1} = 4.56; a (b) (c) indicates statistical significance at the 1% (5%) (10%) level; R^2 is the goodness of fit statistic.

TABLE 2: ESTIMATED COEFFICIENTS FOR THE LOGARITHMIC R AND D EQUATIONS*

EQN, SAMPLE	UNITY	CR4	IGF	VI	RNS	S	KI	PS	$\frac{KAT}{S}$	$\frac{KR}{S}$	λ_R	$\frac{RL}{S}$	R^2
4C	-.704P0	.326M1	-.675P0	.262P0[b]	-.115M1	.649M1	.362M1	-.378P0	-.500M2	.953P0[a]	.270[a]		.95
4E	-.113P1[a]	.118P0[b]	-.200M1	.356P0[a]	-.395M1	-.249M2	-.561M1	.115P0	-.642M2	.978P0[a]	.347[a]		.90
4H	-.324P1[b]	.305P0[c]	-.593P0	.586P0[b]	-.136P0	-.202P0	-.405P0[b]	.131P1	-.107M1	.983P0[a]	.316[a]		.58
4T	-.248P1	-.245M2	.269P1	.364P0	.197P0[c]	-.754P0[b]	-.364P0[c]	.498P1[b]	-.355M1[b]	.110P1[a]	.831[a]		.89
5C	-.814P0[c]	.637M1	-.798P0[c]	.181P0[c]	-.798M2	.580M1	.119M1	-.355P0	-.391M2	.107P1	.270[a]	-.569M1[a]	.96
5E	-.328P0	.674M1[c]	.886M1	.188P0[b]	-.270M1	-.271M1	-.144M1	.198P0	.267M2	.165P0	.347[a]	.806P0[a]	.93
5H	-.323P1[b]	.290P0	-.743P0	.699P0[b]	-.128P0	-.155P0	-.438P0[b]	.110P1	-.177M1	.109P1[a]	.316[a]	-.111P0[c]	.59
5T	-.949P0	-.357M1	.108P1	.129P0	.145P0[b]	-.152P0	-.238P0[c]	.123P1	-.971M2	.123P0	.831[a]	.896P0[a]	.97
6C	-.191P1[c]	.346P0[c]	-.388P1[a]	.150P1[a]	-.664M1	.182P0	.294M1	-.933P0	.284M1[b]			.115P0[a]	.73
6E	-.197P0	.584M1	.113P0[b]	.168P0[b]	-.223M1	-.278M1	-.783M2	.207P0	.485M2			.960P0[a]	.93
6H	-.657P1[a]	.820P0[a]	-.101P0	.106P1[a]	-.139P0	-.395P0[c]	-.275P0	.205P1[c]	.120M1			.223P0[b]	.39
6T	-.118P1	-.298M1	.948P0	.105P0	.146P0[b]	-.110P0	-.239P0[c]	.102P1	-.759M2			.989P0[a]	.97

* The dependent variable is the logarithm of R and D intensity, log (R/S). All variables except λ_R are also taken as logarithms. For samples and notation for symbols, M, P, a, b, c, R^2, see Table 1.

the (flexible accelerator) model of R and D expenditures is confirmed.

The indicated values of λ_R are determined in the non-linear estimation of EQN 1 and 4 for the linear and logarithmic equation forms respectively. Although the λ_R are all quite statistically significant, the effect on the R^2 statistics and coefficient values (other than that of KR) of assuming higher or lower values of λ_R ($\pm.20$) is minimal, indicating that the past observed values of R and D intensity are quite serially correlated. In fact, the past R and D intensities are so serially correlated that RL/S (once lagged R and D intensity) is such a good proxy for KR that it explained slightly more of current R and D intensity than did KR/S (note that EQN 3 has higher R^2 than EQN 1 while EQN 6 has R^2 as good as those of EQN 4).

Concentration and growth appear to have no consistent and statistically significant impact on R and D intensity. Vertically integrated firms are somewhat more R and D intensive, perhaps because they can better implement the results of R and D through the multi-stage coordination of production, they can more fully appropriate the benefits of R and D since vertical integration is an entry barrier, and also by having a greater value added to sales ratio, they have proportionately more funds to finance (risky) R and D programs. Specialized firms in the transportation equipment industry, and possibly those in electrical industry, are

somewhat more R and D intensive (an inability to share joint R and D costs among several product lines necessitates more R and D for the one or few product lines produced). Firms with large sales volumes in the chemical, transportation equipment and possibly machinery industries are less R and D intensive, possibly indicating some diseconomies of scale in R and D programs.

Capital intensive firms in the transportation equipment and machinery industries, and possibly those in the chemical industry, appear to be less research intensive, possibly because they are reluctant to modify plant (and prematurely write off sunk costs) in implementing the results of potential R and D programs. Firms with large asset bases (reflecting large absolute capital requirements), particularly in the chemical industry, may perceive themselves to be so immune to new entry as to undertake greater amounts of appropriable R and D. Firms with high advertising intensities seem somewhat less research intensive. Perhaps they substitute advertising for R and D effort (in an attempt to raise entry barriers or indulge in non-price competition), particularly in the transportation equipment and chemical industries. Finally firms with high levels of previous R and D intensity seem to undertake higher levels of current R and D (to replace and augment the current R and D stock).

The results of estimating the patent intensity equations are presented in Tables 3 and 4. EQN 7 and 10 are

TABLE 3: ESTIMATED COEFFICIENTS FOR THE LINEAR PATENT EQUATIONS*

EQN, SAMPLE	UNITY	CR4	$CR4^2$	IGF	VI	RNS	1/S	S	KI	PS	$\frac{KAT}{S}$	$\frac{R}{S}$	$\frac{MK}{S}$	λ	$\frac{PL}{S}$	$\frac{EP}{S}$	λ_p	R^2
7C	-.317M1	.342M3	-.308M5	-.622M1	.454M2	.547M2	.251P1[a]	-.813M5[b]	.188M1	.153M1[a]	-.157P0[c]	-.189P1[a]	.419P1[a]	.413[a]				.64
7E	-.150P0[a]	.270M2[c]	-.251M4[c]	-.308M2	.169M1	-.242M1[c]	.249P1[a]	-.645M5[b]	-.803M2	.211M1[a]	-.657P0[a]	-.183P1[a]	.424P1[a]	.368[a]				.60
7M	-.270M1	.235M2[c]	-.286M4[c]	.559M2	.100P0[a]	-.397M1[a]	.106P1[b]	-.154M5	.489M2	-.180M2	-.107P0	-.929P0[b]	.518P0[b]	.708[b]				.30
7T	-.119P0	.108M3	-.243M5	.413M1	.211M1	-.142M1	.545P1[a]	-.810M6	.735M1[b]	.118M1[b]	-.401P0	-.723P0	.473P0	.597[a]				.55
8C	.104P0[b]	.775M5	.368M6	-.997M1[a]	-.413M2	.793M2	-.262P0	-.416M6	.304M1[c]	-.503M3	-.449M1	.169M1			.858P0[a]			.90
8E	-.600M1	.396M4	.905M6	-.547M2	-.169M1	-.868M2	.189P1[a]	-.281M5	.127M1	.117M1[b]	-.765P0[a]	.423P0[c]			.536P0[a]			.67
8M	-.605M1	.204M2[c]	-.246M4[c]	.196M1	.480M1[b]	-.151M1[b]	.456P0	-.569M4	.673M2	.451M3	.566M1	-.123P0			.616P0[a]			.62
8T	-.141M1	-.245M3	.151M5	.194M1	.266M1	-.327M2	-.691P0	-.112M7	.451M1[b]	-.820M3	-.131P0	.169P0			.688P0[a]			.85
9C	.946M1[b]	-.186M3	.263M5	-.105P0[a]	-.446M2	.994M2[c]	.993M1	-.115M5	.315M1[b]	.260M2	-.381M1					.172P1[a]	.671[a]	.89
9E	-.629M1[c]	-.183M3	.358M5	-.447M2	.229M1	.369M3	.173P1[a]	-.292M5	-.119M1	.124M1[b]	-.878P0[a]					.750P0[a]	.553[a]	.65
9M	-.544M1	.170M2[c]	-.190M4[c]	.405M2	.391M1[b]	-.116M1[c]	.427P0	-.115M5	.435M2	.228M2	-.604M1					.276P0[a]	.269[c]	.68
9T	-.206M1	.225M3	-.261M5	-.776M2	.406M1[b]	.906M4	.401P0	-.109M6	.456M1[a]	.226M2	-.300M1					.176P0[a]	.966[b]	.92

* The dependent variable is patent intensity, P/S. For samples and notation for symbols, M, P, a, b, c, R^2, see Table 1.

TABLE 4: ESTIMATED COEFFICIENTS FOR THE LOGARITHMIC PATENT EQUATIONS[a]

EQN, SAMPLE	UNITY	CR4	IGF	VI	RNS	S	RI	PS	$\frac{EAT}{S}$	$\frac{R}{S}$	$\frac{RK}{S}$	λ	$\frac{PL}{S}$	$\frac{EP}{S}$	λ_p	R^2
10C	.677P1[a]	-.119P1[a]	.356P1[b]	.503P0[c]	-.336P0[a]	.558P0[b]	.101P1[a]	-.402P1[a]	.244M1	-.141P0	.356P0[b]	.266[a]				.55
10E	.320P1[a]	-.203P0	-.735M1	.263P0	-.969M1	.891P0[a]	.726P0[a]	-.465P1[a]	-.534M2	-.151M1	.283P0[a]	.037[a]				.43
10N	-.593P0	-.838M1	.132P1	.339P0[c]	-.503P0[a]	.181P0	.143M1	-.190P1[b]	.196M1	.352M1	.170P0[c]	.879				.33
10T	-.522P1	.131P1[b]	.164P1	.763P0[b]	-.769P0[a]	-.143M1	.563P0	-.154P1[c]	.123M1	-.783M1	.108P0	.163[a]				.66
11C	.567P1[a]	-.980P0[a]	.272P1[c]	.340P0	-.249P0[b]	.412P0[c]	.999P0[a]	-.336P1[b]	-.315M1[c]	.203P0[c]			.865M1[a]			.57
11E	.294P1[a]	-.331P0[b]	.113P0	-.233M2	-.705M1	.885P0[a]	.770P0[a]	-.472P1[a]	.634M2	.247P0[b]			.606M1[a]			.41
11N	-.102P1	.956M2	.132P1[c]	.994M1	-.176P0[b]	.435M1	-.848M1	-.459P0	.105M1	.503M1			.600P0[a]			.61
11T	-.308P1	.798P0[b]	.272P1	.567P0[b]	-.238P0[c]	-.128P0	.115P0	.151P0	.446M2	.767M1			.694P0[a]			.84
12C	.228P1[b]	-.472P0[b]	-.575P0	.176P0	-.582P0[c]	.160P0	.438P0[a]	-.116P1	.678M2					.788P0[a]	.379[a]	.83
12E	.105P1[c]	-.135P0	.727M1	.297P0	.730M1	.570P0[a]	.442P0[a]	-.285P1[a]	-.136M1					.580P0[a]	.359[a]	.64
12N	-.157P1[b]	.746M1	.128P1[c]	.152P0	-.142P0[c]	.454M1	-.122P0	-.306P0	.858M2					.681P0[a]	.463[a]	.62
12T	-.383P1[c]	.822P0[b]	.184P0	.610P0[b]	-.231P0[c]	-.193P0	.856M1	.636P0	-.497M2					.674P0[a]	.589[a]	.83

[a] The dependent variable is the logarithm of patent intensity, log (P/S). All variables except λ_R and λ_p are expressed as logarithms. For samples and notation for M, P, a, b, c, R^2, see Table 1.

analogues of equation (18)'. The coefficient λ, which is estimated using non-linear least squares, is employed in the lag structure implicit in computing RK (see equation (18)'). The smaller is λ, the shorter the lag between R and D and subsequent patent application, with the lags being shortest for electrical products and longest for machinery.

The coefficients of EQN 7 (typically supported by similar coefficients for EQN 10) provide direct insight into the propensity to patent (pp) the results of R and D expenditures. Firms in 3 and 4 digit S.I.C. industries having low to medium concentration ratios are most likely to patent the results of previous R and D expenditures. For example, patent intensity for a ceteris paribus volume of R and D is greatest for electrical firms facing a CR4 of around 50% and for machinery firms facing a CR4 of about 40%. Although not statistically significant, "critical" CR4's are about 50% and 20% respectively for chemical and transportation equipment firms. Although it is not obvious why firms facing lower concentration ratios patent less (unless they rely more on industrial secrecy or lack access to the patent application mechanism), firms facing higher concentration may view themselves as so well established as to discount the threat of imitators and the associated need to patent.

Growth has no consistent effect on pp, while vertical integration appears to increase it (especially for the

machinery industry), perhaps because a high value added to sales ratio indicates an abundance of funds for patent application purposes. Specialization has a generally negative impact on pp, perhaps because the specialized firm, having fewer products and processes, has less familiarity and contact frequency with the patent application process. Sales volume has a mixed role; a negative effect on pp in the linear specification and a positive effect on pp in the logarithmic specification.

Capital intensity has a generally positive (but only weakly significant) effect on pp, perhaps because capital intensive firms have more to lose (sunk costs) if their inventions are copied by others. Absolute firm size has a generally positive impact on pp in the linear specification but a consistently negative effect in the logarithmic specification (the latter seems more plausible since capital barriers may be good substitutes for patent barriers). Advertising intensity has a statistically significant negative effect on pp for the chemical and electrical samples, suggesting that product differentiation barriers to entry are good substitutes for patent barriers; also R and D in advertising-intensive industries may not be as patentable (eg. style or colour changes). Except in the transportation equipment industry (where some R and D may be unpatentable), there exists a statistically significant causal relationship between R and D intensity and patent intensity.

EQN 8 and 11 are the analogues of equation (20). They seem to better explain patent intensity than EQN 7 and 10 respectively (i.e. R^2 are higher). However, because PL/S better explains patent intensity than does R and D intensity, many other variables (eg. CR4, S, FS) are not as important as they were in EQN 7 and 10. However, the role of these variables remains qualitatively the same in determining pp.

EQN 9 and 12 are analogues for equation (22). Not surprisingly (since PL/R and KP/R are highly correlated), results are quite similar to those obtained for EQN 8 and 11 (and 7 and 10). The depreciation rates for patents (λ_p) in EQN 9 are relatively low for the chemical, machinery and transportation equipment industries and relatively high for electrical products (where rapid obsolescence is associated with the age of the semiconductor). Depreciation rates are higher in EQN 12 for all but the electrical firms (for no apparent reason).

The results of estimating the profitability (gross mark-up) equations are presented in Tables 5A, 5B, 6A and 6B. the "B" tables exclude the vertical integration variable (the ratio of value added to sales) since it played an ambiguous role (one of the components of value added is profits). Except for lower R^2, the estimation results in the B Tables are otherwise similar to those in the A Tables. All equations are analogues for equation (7). The depreciation rates λ_R and λ_p are derived from the prior non-linear esti-

TABLE 5A: ESTIMATED COEFFICIENTS FOR THE LINEAR PROFIT EQUATIONS*

EQN. SAMPLE	UNITY	CR4.$\frac{KT}{S}$	$CR4^2$.$\frac{KT}{S}$	IGF.$\frac{KT}{S}$	VI.$\frac{KT}{S}$	RNS.$\frac{KT}{S}$	KI.$\frac{KT}{S}$	FS.$\frac{KT}{S}$	$\frac{KT}{S}$	$\frac{KAT}{S}$	$\frac{KRT}{S}$	λ_R	$\frac{KPT}{S}$	λ_R	R^2
13C	.123PO[a]	.477M2[c]	-.513M1[c]	.262PO[b]	.338PO[a]	.756M2	.561M1	.142M1[a]	-.588PO[a]	.715M1	.236M1	.375[a]			.76
13E	.144PO[a]	-.258M2[c]	.306M4[c]	-.407M2	.352PO[a]	.251M1[c]	.250M1	.770M2[b]	-.114PO[b]	-.855M1	.285PO[a]	.458[a]			.63
13N	.136PO[a]	.368M2[c]	-.485M4[c]	.102PO	.293PO[a]	.375M1[a]	.261PO[a]	.746M2[b]	-.378PO[a]	-.823M1	.439PO[a]	.546[a]			.77
13T	.135PO[a]	.418M2	-.305M4	.181PO	.475PO[a]	.549M2	.144PO[c]	.121M1[c]	-.563PO[b]	.128PO	.360M1	.403[a]			.53
14C	.121PO[a]	.491M2[c]	-.525M4[c]	.248PO[b]	.351PO[a]	.825M2	.573M1	.137M1[a]	-.540PO[a]	.629M1			-.225M1	.671[a]	.77
14E	.134PO[a]	-.366M2[b]	.407M4[b]	-.499M2	.418PO[a]	.428M1[b]	-.456M1	.978M2[b]	-.809M1	-.113PO			-.317M1	.333[a]	.39
14N	.115PO[a]	.611M2[a]	-.703M4[a]	.953M1	.421PO[a]	.163M1	.162PO[a]	-.291M2	-.301PO[a]	-.170PO			-.997M1[a]	.269[a]	.76
14T	.137PO[a]	.398M2	-.280M4	.256PO	.482PO[a]	-.883M2	.162PO[b]	.972M2[c]	-.616PO[b]	.151PO			-.163PO[c]	.966[b]	.56
15C	.122PO[a]	.466M2[c]	-.505M4[c]	.261PO[b]	.340PO[a]	.875M2	.647M1[b]	.138M1[a]	-.552PO[a]	.610M1	.295M1	.375[a]	-.252M1	.671[a]	.77
15E	.160PO[a]	-.212M2	.226M4	-.361M2	.378PO[a]	.152M1	.559M1	.477M2[c]	-.141PO[b]	.187M2	.383PO[a]	.458[a]	-.755M1[a]	.353[a]	.66
15N	.137PO[a]	.419M2[b]	-.546M4[b]	.108PO[c]	.340PO[a]	.202M1[c]	.241PO[a]	.216M2	-.346PO[a]	-.873M1	.396PO[a]	.546[a]	-.860M1[a]	.269[a]	.80
15T	.138PO[a]	.389M2	-.275M4	.264PO	.477PO[a]	-.110M1	.170PO[b]	.919M2	-.624PO[b]	.173PO	.394M1	.403[a]	-.164PO[c]	.966[b]	.56

* The dependent variable is the ratio of before tax profits, including current interest, R and D and advertising outlays, to sales, π/S. For samples and notation for symbols M, P, a, b, c, R^2, see Table 1. Also note that one observation was dropped in estimating the profit equations for the machinery industry (it had a large negative profit). (Cont'd).

TABLE 5B: ESTIMATED COEFFICIENTS FOR THE LINEAR PROFIT EQUATIONS (CONT'D)

EQN, SAMPLE	UNITY	CR4.$\frac{KT}{S}$	$CR4^2$.$\frac{KT}{S}$	IGF.$\frac{KT}{S}$	RNS.$\frac{KT}{S}$	K1.$\frac{KT}{S}$	PS.$\frac{KT}{S}$	$\frac{KT}{S}$	$\frac{KAT}{S}$	$\frac{KRT}{S}$	λ_R	$\frac{KPT}{S}$	λ_P	R^2
16C	.424M1[c]	-.927M3	-.292M6	.287P0[b]	.952M2	.262M1	.711M2[c]	-.191P0	.499M2	.238P0[a]	.375[a]			.65
16E	.983M1[a]	-.110M2	.111M4	.525M2	.389M1[b]	.130P0[b]	.193M2	.119M1	-.140P0	.416P0[a]	.458[a]			.47
16M	.122P0[a]	-.162M2	.202M4	.162P0[c]	.456M1[a]	.389P0[a]	.683M2[c]	-.288P0[b]	.107P0	.695P0[a]	.546[a]			.68
16T	.755M1[b]	.294M2	-.181M4	.570P0[b]	.212M2	.150P0[c]	.800M3	-.701P0[b]	.156P0	.185P0	.403[a]			.39
17C	.661M2	-.158M3	-.377M5	.159P0	.496M2	-.613M1	.335M2	.525M1	.250M1			.286M1	.671[a]	.61
17E	.655M1[b]	-.234M2	.263M4	.550M2	.716M1[a]	.359M1	.566M2	.980M1[c]	-.249P0			.139M1	.353[a]	.37
17M	.684M1[b]	-.646M3	.272M4	.170P0[c]	.415M1[b]	.296P0[a]	-.458M2	-.138P0	.429M1			-.325M1	.269[a]	.56
17T	.674M1[c]	.302M2	-.170M4	.628P0[b]	-.720M2	.134P0[c]	-.123M4	-.727P0[b]	.909M1			-.158P0	.966[b]	.40
18C	.422M1[c]	-.964M3	-.652M8	.287P0[b]	.982M2	.282M1	.699M2[c]	-.189P0	.232M2	.240P0[a]	.375[a]	-.620M2	.671[a]	.65
18E	.106P0[a]	-.566M3	.518M5	.597M2	.334M1[c]	.154P0[a]	-.159M3	.885M3	-.879M1	.484P0[a]	.458[a]	-.468M1[c]	.553[a]	.49
18M	.122P0[a]	-.175M2	.219M4	.168P0[c]	.398M1[b]	.390P0[a]	.488M2	-.271P0[b]	.116P0	.694P0[a]	.546[a]	-.331M1	.269[a]	.69
18T	.785M1[b]	.265M2	-.152M4	.653P0[b]	-.130M1	.175P0[c]	-.208M2	-.761P0[b]	.199P0	.189P0	.403[a]	-.159P0	.966[b]	.41

TABLE 6A: ESTIMATED COEFFICIENTS FOR THE LOGARITHMIC PROFIT EQUATIONS*

EQN, SAMPLE	UNITT	CR4	IGP	VI	RMS	KI	PS	$\frac{KT}{S}$	$\frac{KAT}{S}$	$\frac{KRT}{S}$	λ_R	$\frac{KPT}{S}$	λ_p	R^2
19C	$-.705P0^{c}$	$-.127P0^{c}$	$.175P1^{a}$	$.322P0^{a}$	.308M1	$.176P0^{b}$	$.200P0^{b}$	$.379P0^{b}$	.275M2	$.168P0^{a}$	$.270^{a}$			.79
19E	$-.447P0^{c}$	-.213M1	.105P0	$.837P0^{a}$	.120M1	$.169P0^{b}$	$.179P0^{b}$	$-.236P0^{c}$	.799M2	$.113P0^{a}$	$.347^{a}$			.60
19N	$-.126P0^{a}$	-.152M1	.337P0	$.743P0^{a}$	$.958M1^{b}$	$.142P0^{c}$	$.430P0^{a}$	-.292M1	-.797M2	.608M1	$.316^{a}$			.59
19T	$-.236P1^{b}$	.273P0	-.424P0	$.719P0^{a}$	.687M2	$.445P0^{a}$	$.463P0^{b}$	$-.638P0^{c}$	.756M2	-.186M1	$.831^{a}$			.59
20C	$-.111P1^{b}$	-.435M1	$.111P1^{b}$	$.517P0^{a}$	.144M1	$.126P0^{c}$	.159P0	$.553P0^{a}$	.925M2			-.280M1	$.379^{a}$	.72
20E	$-.856P0^{a}$	.887M2	$.129P0^{c}$	$.926P0^{a}$	.282M1	$.105P0^{c}$	$.229P0^{b}$	-.465M1	.977M2			-.122M2	$.359^{a}$	.56
20N	$-.151P1^{a}$	.390M1	.343P0	$.851P0^{a}$	.231M1	$.126P0^{c}$	$.221P0^{c}$	.122P0	-.533M2			$-.133P0^{a}$	$.463^{a}$	.62
20T	$-.270P1^{a}$	$.420P0^{b}$	-.239P0	$.759P0^{a}$	-.902M1	$.507P0^{a}$	.201P0	$-.605P0^{c}$	.108M1			$-.118P0^{c}$	$.589^{a}$	.62
21C	-.447P0	$-.174P0^{c}$	$.199P1^{a}$	$.335P0^{a}$	.124M1	$.225P0^{a}$	.130P0	$.360P0^{b}$	.500M2	$.183P0^{a}$	$.270^{a}$	$-.538M1^{c}$	$.379^{a}$	.76
21E	$-.399P0^{c}$	-.266M1	.108P0	$.834P0^{a}$	.675M2	$.184P0^{b}$	$.159P0^{c}$	$-.248P0^{c}$	.853M2	$.121P0^{a}$	$.347^{a}$	-.224M1	$.359^{a}$	.60
21N	$-.120P1^{a}$	-.219M1	.472P0	$.791P0^{a}$	.204M1	$.151P0^{b}$	$.252P0^{b}$	-.253M1	-.527M2	$.857M1^{c}$	$.316^{a}$	$-.143P0^{a}$	$.463^{a}$	.62
21T	$-.289P1^{a}$	$.412P0^{b}$	-.208P0	$.774P0^{a}$	-.832M1	$.492P0^{a}$	.269P0	$-.578P0^{c}$	.929M2	-.266M1	$.831^{a}$	$-.121P0^{c}$	$.589^{a}$	.62

* The dependent variable is the logarithm of the ratio of before tax profits, including current interest, R and D and advertising outlays, to sales, log (π/S). All variables except λ_R and λ_p are expressed as logarithms. For samples and notation for M, P, a, b, c, R^2, see Table 1. (Cont'd).

TABLE 6B: ESTIMATED COEFFICIENTS FOR THE LOGARITHMIC PROFIT EQUATIONS (CONT'D)

EQN, SAMPLE	UNITT	CR4	IGP	RMS	KI	PS	$\frac{KT}{S}$	$\frac{KAT}{S}$	$\frac{KRT}{S}$	λ_R	$\frac{KPT}{S}$	λ_P	R^2
22C	-.801P0[c]	-.180P0[c]	.200P1[a]	.451M1	.103P0[c]	.181P0[c]	.645P0[a]	-.426M2	.226P0[a]	.270[a]			.73
22E	-.787P0[b]	-.240M1	.146P0[c]	.359M1	.235P0[a]	.332M1	.109P0	-.191M3	.204P0[a]	.347[a]			.36
22M	-.146P1[a]	.236M1	.822P0	.937M1[b]	.232P0[b]	.332P0[b]	.167P0	-.710M3	.208P0[a]	.316[a]			.40
22T	-.326P1[a]	.404P0[c]	.214P1	-.761M2	.316P0[c]	.312M1	.242P0	.865M2	-.221M3	.831[a]			.39
23C	-.174P1[a]	-.579M1	.107P1[c]	.474M1	-.848M1	.157P0	.118P1[a]	-.229M2			-.822M6	.379[a]	.64
23E	-.167P1[a]	.352M1	.201P0[c]	.746M1[c]	.119P0[c]	.109P0	.552P0[a]	.133M2			.750M2	.359[a]	.25
23M	-.242P1[a]	.218P0[b]	.643P0	.595M1	.184P0[b]	.108P0	.678P0[a]	.260M2			-.468M1	.463[a]	.34
23T	-.356P1[a]	.484P0[c]	.235P1[c]	-.567M1	.337P0[b]	-.940M1	.306P0	.972M2			-.641M1	.589[a]	.40
24C	-.580P0	-.222P0[b]	.222P1[a]	.296M1	.143P0[c]	.119P0	.637P0[a]	-.255M2	.241P0[a]	.270[a]	-.469M1[c]	.379[a]	.74
24E	-.717P0[b]	-.315M1	.150P0[c]	.284M1	.256P0[a]	.541M2	.899M1	.625M3	.215P0[a]	.347[a]	-.316M1	.359[a]	.36
24M	-.143P1[a]	.210M1	.928P0[c]	.452M1	.242P0[b]	.214P0[c]	.178P0	.133M2	.230P0[a]	.316[a]	-.921M1[c]	.463[a]	.42
24T	-.358P1[a]	.481P0[c]	.236P1[c]	-.561M1	.336P0[b]	-.895M1	.309P0	.961M2	-.162M2	.831[a]	-.643M1	.589[a]	.40

mation of the R and D and patent intensity equations, but again overall results are robust with respect to the choice of λ_R and λ_p over a wide range ($\pm.20$).

The concentration variable experiences mixed coefficient sign and significance levels. Only for the transportation equipment industry is it consistently positive and significant. Whenever statistically significant, and especially in the B specifications, industry growth and specialization have consistently positive coefficients. Vertical integration has a consistently positive and statistically significant coefficient, perhaps more because it directly reflects profits (through its value added component) than because it reflects entry barriers. Capital intensity has a frequent positive impact upon profitability, perhaps because it is collinear with KT/S. Firm size has a somewhat less frequent positive impact on profitability, probably in its role as a measure of capital barriers. The total capital stock variable has a mixed sign, but this reflects its interaction with the intercept and other variables with which it appears as a cross-product (eg. IGF). Advertising capital appears to be no more profitable than tangible capital, whereas R and D capital (for most specifications) is considerably more profitable for firms in the chemical, electrical and machinery industries (and about as profitable for firms in the transportation equipment industry). Patent capital, whether specified alone or jointly with R and D capital, seems to

generate little excess profit beyond that associated with the R and D itself and may even suggest a lower profit for the associated R and D. Perhaps a greater patent stock intensity (for the given R and D stock intensity) signifies a greater perceived need to patent the results of R and D and even then some further difficulty in appropriating the full benefits of invention (i.e. outsiders can and do copy). In this regard, patenting appears to be a defensive (profit-protecting) rather than an offensive (profit-enhancing) undertaking for sample firms.

6. POLICY IMPLICATIONS AND CONCLUSIONS

R and D expenditures and patenting activity, as measures of desirable innovation, can be enhanced by restricting product differentiation (advertising) barriers to entry through controls on advertising frequency, content, product labelling, et cetera. In addition they might be encouraged by a more permissive attitude toward vertical mergers. Since neither R and D nor patenting is consistently affected by industry concentration, the promotion of competition would seem to have little obvious detrimental effect on innovation while yielding (widely recognized) higher levels of static efficiency.

Although R and D capital seems to be more profitable than tangible capital, it appears to lose some of this advantage when the patent intensity rises (i.e. results must

be patented to ensure even partial appropriability). Hence the benefit-cost ratios, in terms of excess profitability, for patenting are relatively low since patenting represents a partially effective defensive measure (in competitive industries) and an option in concentrated, high entry barrier industries. Hence no clear evidence exists for reducing patent breadth or life. In fact, broader, longer-life patents might be justified in competitive, low entry barrier U.S. industries.

REFERENCES

Evans, M.K. (1969), Macroeconomic Theory: Theory Forecasting and Control, (New York: Harper and Row).

Gillen, D.W., A.W. Jenkins and W.C. Riddell (1980), "The Propensity to Patent and the Major Beneficiaries of the Canadian Patent System", Report for Department of Consumer and Corporate Affairs, Ottawa, Canada.

Grabowski, H.G. and D.C. Mueller (1978), "Industrial Research and Development, Intangible Capital Stocks, and Firm Profit Rates", Bell Journal of Economics 9, 328-343.

Howe, J.D. and D.G. McFetridge (1976), "The Determinants of R and D Expenditures", Canadian Journal of Economics 9, 57-71

Pakes, A. and Z. Griliches (1980), "Patents and R and D at the Firm Level: A First Look", NBER Working Paper No. 561.

Taylor, C.T. and Z.A. Silberston (1978), The Economic Impact of the Patent System, (Cambridge University Press).